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Full Length Research Paper

Evaluation of common vetch (*Vicia sativa* L.) as living mulch for ecological weed control in citrus orchards

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Weeds are one of the most important problems in newly established orchards. Especially in organic orcharding, the importance of weed management is much more than conventional orcharding. Therefore, importance of alternative methods to chemical control of weeds is increasing. This study was conducted to quantify the effects of common vetch (*Vicia sativa* L.) as living mulch on weeds and evaluate the availability of common vetch in organic citrus production. The study was carried out in Mandarin orchard which was established specially for this research in research and implementation area of the Plant Protection Department of Çukurova University in Turkey, in a three- year-period. Living mulch and control plots were placed between rows in newly established mandarin orchard and plots were maintained at the same locations until the end of the experiment. In this study, effects of the living mulch application on density, cover proportion, biomass, dry weight and similarity index of weed species were investigated. Overall three-years results of the study were evaluated, living mulch application reduced weed density and cover proportion average of 42.8% and 45.9% respectively compare to control. Biomass and dry weight of weeds were also reduced by living mulch in all years of the experiment. The results indicate that living mulch application by common vetch is an important alternative weed suppression method for ecological weed management.

Key words: Alternative control, cover crop, ecological agriculture, mandarin, mulch, weed management.

INTRODUCTION

Turkey is one of the world's leading citrus producers, and 70% of total national production takes place in the Çukurova region where the field experiment was carried out. As a consequence of this intensive production, weed problems have gained importance. Since the region is characterised by moderate temperatures and plenty of rainfall and irrigation, weed cover reaches up to 49%, despite control attempts (Uygur, 1985). Among the weed control methods applied predominantly in the region are soil tillage and chemical control using herbicides. However, it is a common observation that tillage is done either too often or with the wrong machinery, while herbicides are wrongly used. Suboptimal tillage causes damage to soil structure and tree root systems, as well as unnecessary expenses for material and labour. Negative effects of incorrect herbicide use include risks for human and animal health, development of weed strains resistant to herbicides, shifts to weed species not controlled by the used herbicides within weed communities, damage to non-target organisms and reductions of biological diversity, as well as phytotoxic effects on crops.

In order to reduce these negative effects to minimum, approaches need to be identified and applied that combine maximum efficacy with minimal side effects on agroecosystem. Living mulches have potential to form an important component in such an approach and can be a useful tools for weed suppression in sustainable agricultural systems (Teasdale, 1996; Bond and Grundy, 2001; Kruidhof et al., 2008) including many useful advantages such as; improvement of soil structure (Harris et al., 1966), regulation of soil water content (Hoyt

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and Hargrove, 1986), enhancement of soil organic matter, carbon dynamics and microbiological function (Steenwerth and Belina, 2008), reducing soil erosion (Malik et al., 2000), soil enrichment by nitrogen fixation (Sainju et al., 2001), insectarium for many beneficial arthropod species (Grafton-Cardwell et al., 1999) and enhancement populations of soil macrofauna (Blanchart et al., 2006).

In many studies, best results were obtained from vetch species among living mulch species for weed control because of competitive ability, dense habitus and allelopathic features of these species (Moonen and Barberi, 2002; Batool and Hamid, 2006; Nakatsubo et al., 2008). The present study was conducted to quantify the effects of common vetch as living mulch on weed populations, density, coverage and biomass and also evaluate its potential for ecological weed control in subtropical conditions.

MATERIALS AND METHODS

Experimental set-up

Studies were carried out in 2004 to 2006 at the Research and Implementation Area of the Plant Protection Department of Çukurova University, Turkey. The experimental field was located on clay loam with an organic matter content of 1.46 % and a pH of 7.3. Mandarin (*Citrus reticulata* Blanco) orchard was established with 5 x 5m planting density for this research in spring 2004. The treatments consisted of living mulch and control (no mulch). Common vetch (*Vicia sativa* L.) was used as living mulch between rows and this application had been maintained at the same location for three years. The experimental design was a randomized complete block with four replicates. Soil was tilled by cultivator before sowing and common vetch was sown with sowing machine at the rate of 140 kg ha^{-1} on March 10, 2004, February 17, 2005 and October 25, 2005. Fertilization was applied together with sowing at the rate of 200 kg ha^{-1} (NP 20:20) for every year. Plot size was 144 m^2 (3 x 48 m) for both treatment and 6 quadrats (each 1 m^2) were randomly placed in each plot. These quadrats permanently stayed at the end of the experiment for quantitative observations.

Data collection and analysis

The number of emerged living mulch seedlings was recorded. After the emergence, height and light interception were monitored at 15 days intervals. Light intensity (Lux) was measured from soil surface and top of the plants parallel to the ground in the quadrats within each plot, using a luxmeter. Light interception of living mulch was calculated from differences between light intensity of bottom and upper surfaces. 10 plants were measured in each quadrat for determination of height. Percent coverage of common vetch also determined within all plot at the same intervals. Weed species, density and coverage were determined at 15 days intervals. To make these determinations, five, four and nine observations were made in 2004, 2005 and 2006 respectively. Numbers of the weeds were determined by counting for individual species in the quadrats. But determination of the cover proportion of the weed species was made in all plots.

Weed species were identified from the “Flora of Turkey” (Davis, 1965 to 1988). Relative dominance of weed species was determined by cover proportion of individual species for each year. The first five species with the highest coverage were accepted most dominant for each year. Some species that were the most dominant for one year but another year same species could not be the most dominant. Then, relative dominance of that species was determined by cover proportion in that year. Similarity of the species between years and applications was calculated by the following formula (Odum, 1971):

$$S=2C/(A+B)$$

In this equation; S is the index of similarity; A is the number of species in A application or year; B is the number of species in B application or year; C is the number of species common to both applications or year.

Living mulch and weeds were collected by hand from randomly placed 1 m^2 quadrat for each plot and total biomass (above- and below-ground) was measured 64 days after sowing (DAS), 85 DAS and 171 DAS in 2004, 2005 and 2006 respectively. Dry weight of living mulch and weeds was determined by drying at 65°C for 72 h. Biomass and dry weight measurements of weeds had not been done for individual species. All data from each year analyzed separately. Since the year -treatment interaction has great interest in the evaluation. Variance analysis of dependent variables affected from applications was made with the help of the SPSS package program. Multiple comparison of values of the averages were determined with the Duncan Test at rate of 95% confidence.

RESULTS

Quantitative observations of living mulch

Average density of *Vicia sativa* L. was 109, 75 and 71 plant m^{-2} in 2004, 2005 and 2006 respectively. In 2004 and 2005, height and proportion of soil cover of common vetch increased faster than in 2006 because of spring sowing (Table 1). In 2006, since cover crop was sown in winter, establishment of seedlings and growing of plants were slow. All data of living mulch’s height collecting during three years were correlated with light interception values and calculated shading of living mulch which reaches different height. When the common vetch reached the height of 30 cm, shading rate of the sunlight reaches to 50%. On the other hand, until height of the common vetch reached up to 60 cm, proportion of light interception fastly increased, but after 60 cm, increase of proportion was reduced (Figure 1).

Weed community

In the experimental area including living mulch and control plots, 52 weed species were identified belonging to 24 families during the study. 9 of these species were monocotyledon, 43 species were dicotyledon. Weed diversity was similar between first 2 years, but importance

Table 1. The height and cover proportion of living mulch.

Observation	Height (cm)	Soil cover (%)
	2004	
30 DAS[a]	4.9	36.5
45 DAS	9.2	71.3
60 DAS	21.3	82.5
75 DAS	41.1	88.8
90 DAS	65.1	94.3
	2005	
42 DAS	14.8	54.3
56 DAS	29.0	72.5
70 DAS	53.3	83.8
84 DAS	84.3	92.5
	2006	
45 DAS	14.7	22.3
60 DAS	18.7	35.0
75 DAS	25.0	46.7
90 DAS	30.3	61.7
105 DAS	41.0	75.0
120 DAS	53.0	81.7
135 DAS	66.3	88.3
150 DAS	81.1	88.3
165 DAS	102.3	86.0

[a]DAS is days after sowing.

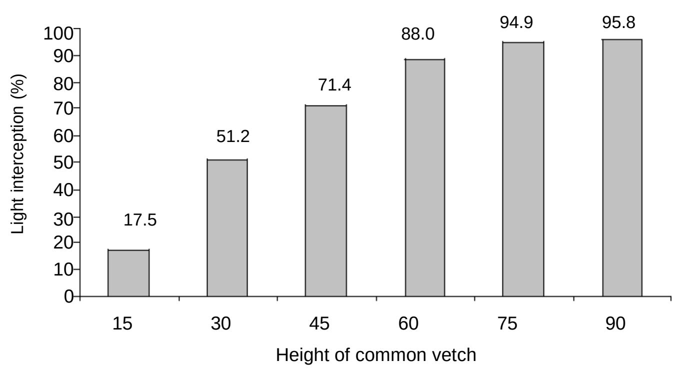

Figure 1. Light interception correlated with height of living mulch.

or dominance of weed species as both cover proportion and density, changed year to year. In 2004, because of the late sowing (10 March, 2004) especially perennial and summery annual weed species like a johnsongrass (*Sorghum halepense* L.), field bindweed (*Convolvulus arvensis* L.), common purslane (*Portulaca oleracea* L.), redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.) were dominant. In 2005, since sowing date or experimental set up was 21 days earlier than in 2004, some winter annual weed species as wild mustard (*Sinapis arvensis* L.) and sterile oat (*Avena sterilis* L.) enhanced their importance while common purslane, common lambsquarters and johnsongrass were losing their value.

In 2006, because of the winter sown (25 October, 2005) main weed species were winter species such as wild mustard, sterile oat, fumitory (*Fumaria asepala* Boiss.), shepherd's-purse (*Capsella bursa-pastoris* (L.) Medik.)

Table 2. Main weed species present at the experimental area and their relative dominance according to years.

Scientific name	Common name	Relative dominance[a]		
		2004	2005	2006
Amaranthus albus L.	Tumble pigweed	++	++	—
Amaranthus retroflexus L.	Redroot pigweed	+++	+++	—
Avena sterilis L.	Sterile oat	++	+++	+++
Capsella bursa pastoris (L.) Medic.	Shepherd's-purse	+	+	+++
Chenopodium album L.	Common lambsquarters	+++	++	—
Convolvulus arvensis L.	Field bindweed	+++	+++	+++
Cyperus rotundus L.	Purple nutsedge	++	++	—
Digitaria sanguinalis (L.) Scop.	Large crabgrass	+	+	—
Fumaria asepala Boiss.	Fumitory	++	++	+++
Portulaca oleracea L.	Common purslane	+++	+	—
Setaria viridis (L.) P.Beauv.	Green foxtail	+	+++	—
Sinapis arvensis L.	Wild mustard	+	+++	+++
Sorghum halepense (L.) Pers.	Johnsongrass	+++	++	—
Others[b c]		+++	+++	+++

[a] The relative dominance degree of weed species was evaluated based on values of coverage +++ : Most dominant ++ : dominant + : non-dominant — : no plants. [b] There were 24, 24, and 15 species with the exception of list in 2004, 2005 and 2006 respectively. [c] Other species have been assessed in bulk.

Table 3. Similarity index of the weed species between applications and years.

	Years of the experiment	Total number of species	Number of common species	Index of similarity
Between applications	I. Year	37	31	0.91
	II. Year	37	32	0.93
	III. Year	28	21	0.86
Between years	I. and II. Years	42	31	0.84
	II. and III. Years	48	17	0.52
	I. and III. Years	48	16	0.49

and field bindweed (Table 2).

Similarity index of the weed species between applications and years was shown in Table 3. Similarity of the weed species between living mulch and control treatments found high in the first two years, but in third year, similarity was slightly reduced. In other words, species diversity between treatments increased.

Weed suppression

Living mulch reduced both weed density and cover proportion of weed in all years of the experiment (Table 4). Basis of the average value of all the observations, living mulch reduced weed densities by 42.1, 42.8 and 43.6% in 2004, 2005 and 2006 respectively, compared with control. Proportion of weed cover was also reduced by living mulch treatment. According to mean values, this reduction was performed by 62.9, 37.8 and 37.1% in 2004, 2005 and 2006 respectively, compared with control. Reduction of both weed density and weed cover increased while habit of living mulch rise up.

Living mulch reduced both biomass and dry weight of weeds in all years of the experiment (Table 5). But no statistical differences determined between treatments at the last two years of the experiment because of the high variation among replicates. Living mulch reduced weed biomass by 48.8, 43.7 and 31.0% in 2004, 2005 and 2006 respectively, compared with control. Dry weight of weeds was also reduced by living mulch treatment. This reduction was performed by 54.8, 56.6 and 40.0% in 2004, 2005 and 2006 respectively, compared with control.

Table 4. The number and cover proportion of weeds in living mulch and control plots.

Observation	Weed density (plant m^{-2})[b,c]		Weed cover (%)[b, c]	
	Living mulch	Control	Living mulch	Control
		2004		
30 DAS[a]	9.3 (3.0) a	6.4 (2.1) a	3.8 (2.2) a	2.5 (2.6) a
45 DAS	49.9 (7.8) a	65.7 (9.7) a	17.5 (4.9) a	14.5 (5.6) a
60 DAS	60.8 (15.0) a	91.0 (17.2) a	23.8 (7.5) a	51.5 (7.4) b
75 DAS	52.6 (19.5) a	112.2 (26.1) b	20.3 (2.1) a	69.3 (7.9) b
90 DAS	39.2 (11.6) a	93.3 (29.3) b	16.8 (2.6) a	83.0 (2.5) b
Mean	42.4 (10.1) a	73.5 (19.0) b	16.4 (8.0) a	44.2 (12.8) b
		2005		
42 DAS	74.0 (18.6) a	61.3 (19.1) a	14.0 (4.6) a	16.3 (7.5) a
56 DAS	110.8 (6.1) a	149.5 (35.0) a	25.8 (6.5) a	41.3 (10.3) a
70 DAS	129.0 (24.2) a	249.5 (98.1) a	37.5 (8.7) a	67.5 (10.4) b
84 DAS	113.5 (10.6) a	287.3 (94.2) b	55.0 (7.1) a	87.5 (2.9) b
Mean	106.8 (25.5) a	186.9 (47.1) b	33.1 (7.8) a	53.1 (9.7) b
		2006		
45 DAS	41.5 (4.2) a	69.0 (20.5) a	11.7 (1.9) a	16.7 (2.7) a
60 DAS	53.4 (9.5) a	86.4 (23.5) a	21.3 (2.6) a	23.3 (4.7) a
75 DAS	65.1 (14.7) a	107.5 (30.6) a	26.0 (1.4) a	35.0 (7.1) a
90 DAS	77.4 (15.4) a	122.9 (35.2) a	27.7 (2.4) a	43.3 (7.5) b
105 DAS	87.8 (16.3) a	133.8 (35.0) a	31.0 (2.9) a	51.7 (6.2) b
120 DAS	80.9 (13.7) a	134.1 (34.5) a	35.0 (4.1) a	56.7 (6.2) b
135 DAS	63.3 (6.1) a	127.5 (35.5) b	38.3 (4.9) a	63.3 (4.7) b
150 DAS	45.2 (8.4) a	103.1 (29.7) b	40.0 (4.1) a	70.0 (5.0) b
165 DAS	34.0 (7.0) a	88.0 (24.7) b	40.0 (4.0) a	70.7 (4.2) b
Mean	61.0 (10.6) a	108.0 (29.8) b	30.1 (3.5) a	47.9 (4.9) b

[a]DAS is days after sowing, [b]Means within line followed by the same letter are not significantly different at P = 0.05 level within years and [c]Figures in parentheses indicate standard deviation.

Table 5. The biomass and dry weight of weeds in living mulch and control plots.

	2004		2005		2006	
	Biomass ($g.m^{-2}$)[a, b]	Dry weight ($g.m^{-2}$)[a, b]	Biomass ($g.m^{-2}$)	Dry weight ($g.m^{-2}$)	Biomass ($g.m^{-2}$)	Dry weight ($g.m^{-2}$)
Weeds in living mulch	576.3 a (127.3)	136.6 a (33.8)	643.8 a (207.6)	142.2 a (54.8)	1576.7 a (375.4)	398.7 a (98.8)
Weeds in control	1125.0 b (352.7)	302.4 b (94.6)	1142.5 a (493.4)	327.4 a (129.8)	2285.0 a (720.5)	664.7 a (189.6)

[a]Means within column followed by the same letter are not significantly different at P = 0.05 level and [b]Figures in parentheses indicate standard deviation.

DISCUSSION

One of the important factors of weed suppression mechanisms of living mulch is light interception. Because plants need light to develop and living mulch is blocking sunlight reaching the weeds. Thus, especially decumbent weed species can not get enough light. Inverse ratio was determined between weed density and living mulch shading when reaches approximately 60% light interception ratio and over in the study (Figure 2). Because height of the common vetch reached up to 60 cm, proportion of light interception reaches a value as high as 88%. Light interception by living mulch in early stage show the effects on weed density after a period of time. Thus Kruidhof et al. (2008) reported that weed suppression is positively correlated to early light

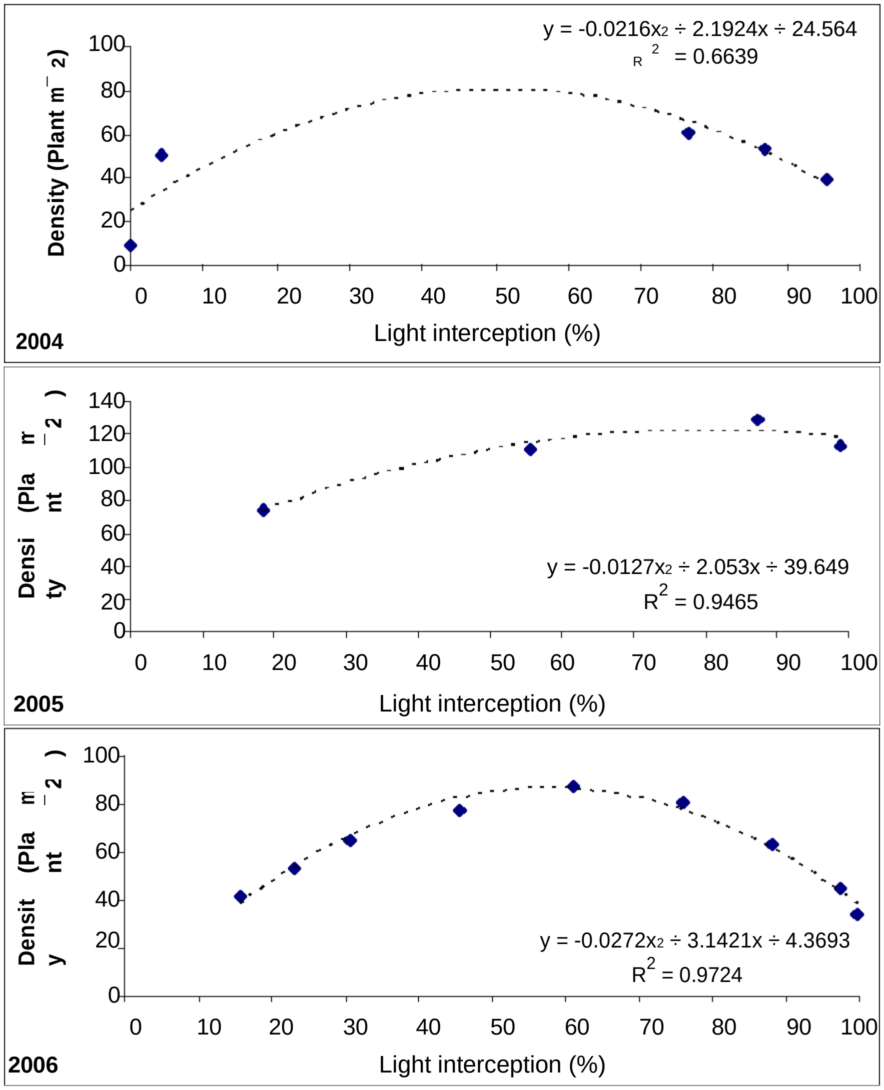

Figure 2. Correlations between weed density and light interception ratio of living mulch.

interception by the living mulch, is sustained by the strong negative correlation between cumulative light interception and weed biomass. Similarly, according to Steinmaus et al. (2008) weed suppression was linked to light interception by the mulch cover for most weed species.

Weed community was similar between first two years of the study but weed flora was different in the third season, because of winter sowing. On the other hand, similarity of weed species between applications was found high. But, in the third year of the experiment, similarity of the species slightly reduced. Since living mulch application for a period of three years in the same area caused partly change in weed flora. Species that could compete with living mulch or adapt to that environment sustained their existence, while others were eliminated with time. Thus Vandermeer (1989) said that, increasing density of plant in a limited area reduce the amount of resources in the environment and species in competition with each other, which limits their living space. Therefore species diversity is declining.

Three-year results of the study were generally evaluated, living mulch treatment reduced weed density and cover proportion in average of 42.8 and 45.9% respectively compared to control. These results are similar to previous studies. For instance, Brandsaeter and Roen (2004) report that, in organic apple production, hairy vetch as living mulch between rows reduced weed population significantly. Similarly, different living mulch species were evaluated in citrus orchard and best results were obtained by common and hairy vetch for weed control (Koloren and Uygur, 2006). On the other hand some weed species were not controlled by living mulch effectively. These species are growing fast and tall like wild mustard (*S. arvensis* L.) and sterile oat (*A. sterilis* L.). Decumbent and short species like field bindweed (*C. arvensis* L.), common purslane (*Portulaca oleracea* L.), green foxtail (*Setaria viridis* L.), speedwell (*V. hederifolia* L.) and puncturevine (*Tribulus terrestris* L.) controlled by living mulch much more effectively.

Finally, the success of weed suppression by living mulches will also depend on the weed species (Liebman and Dyck, 1993), though complete suppression of weeds is usually not achieved (Teasdale, 1996). Therefore, it is necessary to study different combinations of cover crops for living mulch systems in relation to the locally prevailing weed populations. Sowing time of living mulch is also very important for following weed flora. Because some weed species germinate faster than living mulch, some of them germinate simultaneously with mulch species and some germinate after the living mulch. Species that germinate after living mulch can not grow well. Since living mulch species effect as mulch by shading and mechanically blocked. Because of this, winter sowing of common vetch is more effective to control weed species in subtropical Çukurova region. In this way, both winter species and summer species can be controlled. Thus Anugroho et al. (2009) reported that the growth of hairy vetch in subtropical Okinawa was affected by the sowing date. Hairy vetch should be sown from mid-October to early November because of the favorable conditions for its initial growth that prevails when the temperature ranges from 20 to 25°C. Thereby, it produces a high biomass and suppresses the weeds physically in the winter and spring seasons.

The results of the study were generally evaluated, living mulch treatment reduced weed biomass and dry weight. This reduction was performed 41.1% and 50.5% for biomass and dry weight respectively compare to control as the average of three years of the study. Similarly, Meschede et al. (2007) expressed that the biomass accumulation by the living mulches was inversely proportional to the weed biomass. Fisk et al. (2001) reported that, four different legume cover crop species reduced dry weights of annual weeds between rate of 26 and 80% while dry weights of perennial weeds were reduced between rate of 35 and 75%. All these results show that living mulch application by common vetch is an important alternative weed suppression method for ecological weed management.

Especially, winter sowing of common vetch is more effective than summer sowing in terms of weed control. Because of this in organic orcharding, living mulches should be incorporated into weed management programs.

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